

Claims

1. A method for selectively reducing, inactivating or destroying an agent in a heat-sensitive material, the method comprising:
 - a) heating the heat-sensitive material at a rate of at least 50 degrees C per second to a pre-selected temperature of at least 60 degrees C to provide a heated liquid material;
 - b) cooling the heated heat-sensitive material at a rate of at least 100 degrees C per second for a cooling time period;
 - c) circulating the heat-sensitive material, at a flow rate of at least 80 liters per hour, during the heating and the cooling;wherein the reducing or inactivating of the agent occurs while maintaining desirable properties of the heat-sensitive material.
2. The method of claim 1 wherein the heating further comprises exposing the heat-sensitive material to microwave energy.
3. The method of claim 2 wherein a microwave generator produces microwave energy of a frequency of at least 1000 MHz and the microwave generator has a power capacity of at least 10 kW.
4. The method of claim 1 wherein cooling comprises a cooling rate of between 200 and 600 degrees C per second.
5. A method for reducing, inactivating or destroying an agent in a heat-sensitive material, the method comprising:
 - a) circulating the heat-sensitive material, at a flow rate of at least 80 liters per hour,
 - b) heating the heat-sensitive material through the employment of a microwave generator producing microwave energy having a frequency of at least 1000 MHz and a power capacity of at least 10 kW, for a pre-selected time sufficient to heat the heat-sensitive

material at a rate of at least 50 degrees C per second to a pre-selected temperature of at least 60 degrees C, to provide a heated liquid material; and

c) cooling the heat-sensitive material,

wherein the reducing or inactivating of the agent occurs while maintaining desirable properties of the heat-sensitive material.

6. The method of claim 5 wherein the cooling comprises a cooling rate of at least 100 degrees C per second.

7. The method of claim 5 wherein the cooling comprises a cooling rate in the range of 200 degrees C per second to 600 degrees C per second.

8. The method of any one of claims 1 and 5 wherein the heating comprises a heating rate in the range of 100 degrees per second to 450 degrees per second.

9. The method of any one of claims 1 through 7 wherein the pre-selected temperature comprises a temperature in the range of 70 degrees C to 130 degrees C.

10. The method of any one of claims 3 and 5 wherein the microwave generator produces microwaves having a frequency of at least 1000 MHz and the microwave generator has a power capacity in the range of 10 kW to 100 kW.

11. The method of any one of claims 3 and 5 wherein the microwave generator produces microwaves having a frequency of 2450 +/- 50 MHz.

12. The method of any one of claims 3 and 5 wherein the microwave generator has a power capacity of about 30 kW.

13. The method of any one of claims 1 through 7 further comprising controlling the cooling, heating and circulating of the heat-sensitive material through employment of a user interface control module.

14. The method of claim 13 wherein the user interface control module employs SCADA software.

15. The method of any one of claims 1 through 7 wherein the circulating further comprises a flow rate in the range of 80 liter per hour to 500 liters per hour.

16. The method of any one of claims 1 through 7 wherein the cooling further comprises flowing the heat-sensitive material through a heat exchanger.

17. The method of any one of claims 1 through 7 wherein the cooling further comprises flowing the heat-sensitive material through a tube and shell heat exchanger.

18. The method of any one of claims 1 through 7 wherein the cooling further comprises flowing the heat-sensitive fluid through a plurality of heat exchangers.

19. The method of claim 18 wherein one of the plurality of heat exchangers comprises a tube and shell heat exchanger and another of the plurality of heat exchangers comprises a plate heat exchanger.

20. The method of claim 18 further comprising flowing the heat-sensitive material first through a tube and shell heat exchanger and second through a plate heat exchanger.

21. The method of claim 17 wherein the tube and shell heat exchanger comprises a jacketed tube and shell, the jacket comprising a secondary coolant chamber surrounding a primary coolant chamber.

22. The method of 21 wherein the primary and secondary chambers are flowably connected and wherein the coolant in the secondary chamber is received from the primary chamber.

23. The method of claim 21 wherein the primary and secondary chambers receive coolant independently.

24. The method of claim 19 wherein a product inlet to the tube and shell heat exchanger is connected to a product outlet from a microwave waveguide.

25. The method of claim 19 wherein the product outlet of the tube and shell heat exchanger is connected to the product inlet of a second heat exchanger.

26. The method of claim 16 wherein the heat exchanger is cooled by fluid provided from a utility module maintained remotely from the heat exchanger.

27. The method of any one of claims 2 through 7 further comprising heating the heat-sensitive material in a heat-exchanger prior to exposing to microwave energy.

28. The method of claim 27 wherein the heat exchanger employs heated fluid from a utility unit maintained remotely from the fluid processing unit.

29. The method of any one of claims 1 through 7 further comprising circulating the heat-sensitive material at a pre-selected flow rate.

30. The method of any one of claims 3 through 7 wherein the microwave frequency is within the S band.

31. The method of claim 2 wherein the microwave frequency is within the L band.

32. The method of any one of claims 1 through 7 wherein the circulating further comprises pumping the heat-sensitive material.

33. The method of any one of claims 1 through 7 wherein the circulating further comprises pumping the heat-sensitive material through tubing of internal diameter of not more than 1 inch.

34. The method of any one of claims 1 through 7 wherein the circulating further comprises pumping the heat-sensitive material through tubing of internal diameter of between one-tenth of an inch to one-half an inch.

35. The method of any one of claims 1 through 7 wherein the circulating further comprises pumping the heat-sensitive material through stainless steel tubing, the tubing having an internal diameter of not more than one inch.

36. The method of claim 35 wherein the stainless steel tubing has an internal diameter of between one-eighth of an inch to one-half of an inch.

37. The method of any one of claims 1 through 7 wherein the circulating further comprises pumping the heat-sensitive material through TEFLON tubing, the TEFLON tubing having an internal diameter of not more than one inch.

38. The method of any one of claims 1 through 7 wherein the circulating further comprises pumping the heat-sensitive material through both TEFLON tubing and stainless steel tubing each of internal diameter not more than three-quarters of an inch.

39. The method of claim 32 wherein the pumping comprises utilizing a motorized, positive displacement pump.

40. The method of claim 39 wherein the pump is autoclavable.

41. The method of any one of claims 1 through 7 wherein the agent comprises a pathogen.

42. The method of any one of claims 1 through 7 wherein the agent comprises a virus.
43. The method of any one of claims 1 through 7 wherein the agent comprises a bacteria.
44. The method of any one of claims 1 through 7 wherein the heat-sensitive material comprises a protein and wherein maintaining the desirable properties of the heat-sensitive material comprises reducing the activity of the protein by not more than 90%.
45. The method of any one of claims 1 through 7 wherein the heat-sensitive material comprises a protein and wherein maintaining the desirable properties of the heat-sensitive material comprises reducing the activity of the protein by not more than 75%.
46. The method of any one of claims 1 through 7 wherein the heat-sensitive material comprises a protein and wherein maintaining the desirable properties of the heat-sensitive material comprises reducing the activity of the protein by not more than 50%.
47. The method of any one of claims 1 through 7 wherein the heat-sensitive material comprises a protein.
48. The method of any one of claims 1 through 7 wherein the heat-sensitive material comprises a protein hydrolysate.
49. The method of any one of claims 1 through 4 and 6 wherein the cooling time period, during which heat-sensitive material is cooled at a rate of at least 100 degrees C per second, is not more than 0.2 seconds, and wherein the heat-sensitive material is cooled for a total cooling time period of at least 0.2 seconds.
50. The method of claim 49 wherein the cooling time period during which the heat-sensitive material is cooled at a rate of at least 100 degrees per second is not more than 0.15 seconds, and wherein the heat-sensitive material is cooled for a total cooling time period of not more than 6 seconds.

51. A system for reducing, inactivating or destroying an agent in a heat-sensitive material, the system comprising:

- a) a source of microwave energy producing microwaves with a frequency of greater than 1000 MHz and a power supply of greater than 10 kW;
- b) a flow path for providing a flow stream of the heat-sensitive fluid material, the flow stream having a flow rate of greater than 80 L/hr;
- c) a waveguide in microwave contact with the source of microwave energy, the waveguide adapted to receive the flow path for the flow stream within the waveguide;
- d) a cooler adapted to receive the flow path for the flow stream after the flow stream exits the waveguide and capable of cooling the flow stream;
- e) a control module for controlling components of the system,

wherein the agent is reduced , inactivated or destroyed while the desirable properties of the heat-sensitive material are maintained.

52. The system of claim 51, wherein the power supply is contained within a power supply module located remotely from the control module and controlled by the control module.

53. The system of claim 51, further comprising a heat exchanger for heating material in the flow stream prior to the flow stream entering the waveguide.

54. The system of claim 51, further comprising a utility module, the utility module located remotely from the control module and controlled by the control module.

55. The system of claim 54 wherein the utility module comprises a source of cooling fluid for the cooler.

56. The system of claim 54 further comprising a heat exchanger for heating material in the flow stream prior to the flow stream entering the waveguide and wherein the utility module comprises a source of heating fluid for the heat exchanger.

57. The system of claim 54 wherein the utility module comprises a source of cooling fluid for system components.

58. The system of claim 51, wherein the cooler comprises a tube and shell heat exchange cooler.

59. The system of claim 58 wherein the tube and shell heat exchanger cooler comprises a jacketed tube and shell, the jacket comprising a secondary chamber containing cooling fluid surrounding a primary chamber containing cooling fluid.

60. The system of claim 51 wherein the cooler comprises a plurality of heat exchangers.

61. The system of claim 60 wherein one of the plurality of heat exchangers comprises a tube and shell heat exchanger, the tube and shell heat exchanger comprising a flow path surrounded by a chamber containing cooling fluid.

62. The system of claim 61 wherein one of the plurality of heat exchangers comprises a jacketed tube and shell heat exchanger, the jacket comprising a secondary chamber containing cooling fluid surrounding a primary chamber containing cooling fluid .

63. The system of claim 60 wherein one of the plurality of heat exchangers comprises a plate heat exchanger.

64. The system of claim 60 wherein one of the plurality of heat exchangers comprises a plate heat exchanger and another comprises a jacketed tube and shell heat exchanger.

65. The system of claim 51 wherein the cooler comprises more than one heat exchanger and wherein a first heat exchanger cools at a rate of at least 100 degrees C per second and a second heat exchanger cools at a rate of not greater than 100 degrees per second.

66. The system of claim 51 wherein the heat-sensitive material is heated at a rate of at least 100 degrees C per second.

67. The system of claim 51 wherein the microwave generator produces microwave energy having a frequency of 2450 MHz +/- 50 MHz.

68. The system of claim 67 wherein the microwave generator has a power capacity of at least 30 kW.

69. The system of claim 51, wherein the control module comprises a user interface located remotely from the waveguide for remote monitoring of the system.

70. The system of claim 51, further comprising means for monitoring leakage of the microwave energy from the waveguide.

71. The system of claim 51, further comprising means for controlling leakage of the microwave energy from the waveguide.

72. The system of claim 51, wherein the waveguide comprises an applicator region, and the means for controlling leakage comprises an air impermeable pressure window between the waveguide and the applicator region of the waveguide.

73. The system of claim 72, wherein the waveguide applicator region comprises a conductive gasket and a quarter wave choke.

74. The system of claim 51, wherein the flow stream has a flow rate of not less than 300 liters/hour.

75. The system of claim 51, wherein the flow path for the flow stream within the waveguide is secured to a removable plate.

76. The system of claim 51, wherein the source of microwave energy has a power supply of not less than 20 kW.

77. The system of claim 51, wherein the source of microwave energy has a power supply of not less than 30 kW.

78. The system of claim 51, wherein the source of microwave energy has a power supply in the range of 10 kW to 100 kW.

79. The system of claim 51, wherein the frequency of the microwave energy is within the S band spectrum.

80. The system of any one of claims 51 through 79 wherein the flow path comprises a combination of TEFLON and stainless steel of internal diameter ranging between one-eighth of an inch to three-quarters of an inch.

81. The system of any one of claims 51 through 79 wherein the flow stream is produced through the employment of a motorized pump.

82. The system of claim 81 wherein the motorized pump is employed to circulate the heat-sensitive material through a flow path of an internal diameter of not more than one inch.

83. The system of claim 82 wherein the flow path comprises stainless steel.

84. The system of claim 82 wherein the flow path exposed to microwave energy comprises a microwave transparent material.

85. The system of claim 84 wherein the microwave transparent material comprises TEFLON.

86. The system of claim 82 wherein the flow path comprises a combination of stainless steel and TEFLON.

87. The system of claim 51 wherein the heat-sensitive material comprises a protein.

88. The system of claim 51 wherein the agent comprises a virus.

89. A system for thermal processing of a heat-sensitive fluid material comprising:

- a) a source of microwave energy capable of generating microwaves having a frequency of greater than 1000 MHz, the source of microwave energy having a power capacity of at least 10 kW;
- b) a means for providing a flow stream of a heat-sensitive fluid material, the flow stream having a flow rate of at least 80 L/hr;
- c) a waveguide in microwave communication with the source of microwave energy, the waveguide adapted to receive a flow path for the flow stream within the waveguide; and
- d) means for monitoring and controlling the processing by the system.

90. The system of claim 89, further comprising means for pre-heating the heat-sensitive fluid material in the flow stream.

91. The system of claim 89, further comprising means for cooling the heat-sensitive fluid material in the flow stream, the means for cooling capable of cooling the heat-sensitive material at a rate of at least 100 degrees C per second.

92. The system of claim 89, wherein the flow path for the flow stream within the waveguide is secured to a removable plate.

93. A method of thermally reducing or inactivating a bacteria virus in a protein solution, the method comprising the steps of:

a) providing a heat-sensitive fluid in a fluid flow stream having a flow rate of at least 80 liters per hour;

b) exposing the fluid flow stream to microwave energy of frequency of at least 1000 MHz for a pre-selected time sufficient to raise the temperature of the fluid in the flow stream to a pre-selected temperature so as to reduce or inactivate the microorganism or pathogenic agent without substantially altering the desirable properties of the material in the fluid; and

c) rapidly cooling the fluid flow stream.

94. The method of claim 93, wherein the frequency of the microwave energy is within the S band spectrum.

95. The method of claim 93, wherein the frequency of the microwave energy is 2450 +/- 50 MHz.

96. The method of claim 93, wherein the pre-selected time for exposing the fluid flow stream to microwave energy is not more than 0.5 second, the flow rate is at least 80 liters per hour and the rapid cooling comprises first cooling at a rate of at least 100 degrees C per second and second cooling at a rate of not more than 100 degrees per second.